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METHOD FOR FABRICATING A QUARTZ GLASS WAVEGUIDE

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METHOD FOR FABRICATING A QUARTZ GLASS WAVEGUIDE

[Sekieikei garasu hadoro no seizo hoho]

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[There are no amendments to this patent.]

Claims

1. A method for fabricating a quartz glass waveguide characterized in that a WSi mask pattern for creating a pair of core trenches is formed on a low index of refraction cladding layer formed on the surface of an SiO<sub>2</sub> or an Si substrate; core trenches are formed in the aforementioned cladding layer with a low index of refraction using said WSi mask pattern; and cores with desired high indexes of refraction are formed in said core trenches according to the widths of the respective cores.

2. The method for fabricating a quartz glass waveguide described under Claim 1, characterized in that after the WSi film is formed on the low index of refraction cladding layer which is formed on the surface of the SiO<sub>2</sub> or Si substrate; the WSi mask pattern for creating the core trenches is formed through a photolithography step and a dry etching step; the core trenches

are then formed in the cladding layer with a low index of refraction through the dry etching step using said WSi mask pattern; a core film with a desired high index of refraction is formed subsequently in the widths corresponding to those of the respective cores by means of a plasma CVD method so as to bury said trenches; said WSi mask is then removed through the dry etching step after the extra portions of the core film is etched away until the WSi film becomes exposed through the dry etching step; and a cladding layer with a low index of refraction is finally formed over the aforementioned entire etched surface.

3. The method for fabricating a quartz glass waveguide described under Claim 1, characterized in that after the WSi film is formed on the low index of refraction cladding layer which is formed on the surface of the SiO<sub>2</sub> or Si substrate, the WSi mask pattern for creating the core trenches is formed through a photolithography step and a dry etching step; the core trenches are then formed in the low index of refraction cladding layer through the dry etching step using said WSi mask pattern; a core film with a desired high index of refraction is formed subsequently in the widths corresponding to those of the respective cores by means of a plasma CVD method so as to bury said trenches; after the WSi mask pattern is removed through the dry etching step; the extra portion of the core film is then etched away, and a low index of refraction cladding layer is finally formed on top of said surface.

#### Detailed explanation of the invention

[0001]

Technical field of the invention

The present invention pertains to a method for fabricating a quartz glass waveguide which can be utilized for an optical filter, an optical switch, or a dispersion compensation circuit.

[0002]

A method for fabricating a conventional quartz glass waveguide is shown in Figure 9 and Figure 10.

[0003]

First, SiO<sub>2</sub> cladding layer (2) is formed on SiO<sub>2</sub> or Si substrate (1) by means of a plasma CVD method, a sputtering method, or an ion beam method (Figure 9 (a)).

[0004]

Then, core film 3 made of a quartz glass material, such as SiO<sub>2</sub> doped with a refractivity controlling dopant, for example, TiO<sub>2</sub> or GeO<sub>2</sub>, or SiO<sub>x</sub>NyHz, is formed by means of the plasma CVD method, the sputtering method, or the ion beam method (Figure 9 (b)). Furthermore, WSi

film (4) is formed on top of the quartz glass material by means of the sputtering method (Figure 9 (c)). Then, WSi mask pattern (5) for masking the core areas is formed through a photolithography step and a dry etching step (Figure 10 (a)). The two cores (6) are formed of the quartz glass material through the dry etching step (Figure 10 (b)). The quartz glass waveguide is completed with cladding layer (7), which is made of the quartz glass material and covers the cores (Figure 10 (c)).

[0005]

Problem to be solved by the invention

This kind of waveguide-type optical circuit can be used as an optical multiplexer-demultiplexer component in an optical filter, an optical switch, or a dispersion compensation circuit. A desired demultiplexing characteristic can be obtained by regulating the indexes of refraction of the cores (6) and (6) and distance S between the cores (6) and (6) in the optical coupling region.

[0006]

However, in the case of the conventional method shown in Figure 9 and Figure 10, the indexes of refraction of the cores (6) and (6) are decided at the time of the formation of core film (3). Therefore, in order to attain the desired demultiplexing characteristic, dry etching conditions during the step shown in Figure 10 (b) need to be optimized so as to assure that distance S between the cores (6) and (6) is exactly equal to the designed value. However, said dry etching conditions are difficult to optimize, and distance S between the cores (6) and (6) often deviates from the designed value, so that the desired coupler characteristic, that is, 3dB, is difficult to achieve.

[0007]

In order to solve the aforementioned problem, the purpose of the present invention is to present a method for fabricating a quartz glass waveguide so as to attain a desired characteristic for an optical multiplexer-demultiplexer as a component of an optical filter, an optical switch, or a dispersion compensation circuit.

[0008]

Means to solve the problem

In order to achieve the aforementioned goal, in the invention described under Claim 1, a WSi mask pattern for forming a pair of core trenches is formed on a cladding layer with a low index of refraction formed on the surface of an SiO<sub>2</sub> or an Si substrate. Core trenches are formed

in the aforementioned cladding layer with a low index of refraction using said WSi mask pattern. Cores with the desired high indexes of refraction are formed in said core trenches according to the widths of the respective cores.

[0009]

The invention described under Claim 2 is the method for fabricating a quartz glass waveguide described under Claim 1. After the WSi film is formed on the low index of refraction cladding layer, which is formed on the surface of the SiO<sub>2</sub> or Si substrate, the WSi mask pattern for forming the core trenches is formed through a photolithography step and a dry etching step. The core trenches are then formed in the low index of refraction cladding layer through the dry etching step using said WSi mask pattern. A core film with a desired high index of refraction is formed on top of it in the widths corresponding to those of the respective cores by means of a plasma CVD method so as to bury said trenches. Said WSi mask is then removed through the dry etching step after the extra portion of the core film is etched away until the WSi film becomes exposed through the dry etching step. A cladding layer with a low index of refraction is finally formed over the aforementioned entire etched surface.

[0010]

The invention described under Claim 3 is the method for fabricating a quartz glass waveguide described under Claim 1. After the WSi film is formed on the low index of refraction cladding layer, which is formed on the surface of the SiO<sub>2</sub> or Si substrate, the WSi mask pattern for forming the core trenches is formed through a photolithography step and a dry etching step. The core trenches are then formed in the low index of refraction cladding layer through the dry etching step using said WSi mask pattern. A core film with a desired high index of refraction is formed subsequently in the widths corresponding to those of the respective cores by means of a plasma CVD method so as to bury said trenches. After the WSi mask pattern is removed through the dry etching step, the extra portion of the core film is then etched away. A cladding layer with a low index of refraction is finally formed on top of said surface.

[0011]

According to the method of the present invention, after the trenches where the pair of cores are formed is formed in the low index of refraction cladding layer by means of dry etching, distance S between said trenches is measured, and the index of refraction of the core film is regulated so as to attain the desired coupler characteristic, that is 3 dB, based on said measured value in order to obtain the desired coupler characteristic. Therefore, a quartz glass waveguide with a desired characteristic can be realized easily.

[0012]

#### Embodiments of the invention

Ideal embodiments of the present invention will be described in detail below based on the attached figures.

[0013]

The method for fabricating a quartz glass waveguide of the present invention is shown in Figure 2, Figure 3, and Figure 4.

[0014]

In Figure 2 (a), SiO<sub>2</sub> cladding layer (13) is formed on SiO<sub>2</sub> or Si substrate (12) by means of a plasma CVD method, a sputtering method, or an ion beam method. Then, WSi film (14) is formed on top of it by means of the sputtering method (Figure 2 (b)). Next, WSi mask pattern (15) for covering [the entire area] except the areas where cores are to be formed is formed through a photolithography step and a dry etching step (Figure 2 (c)).

[0015]

Then, a pair of trenches (16) for optical multiplexing/demultiplexing cores are formed by means of dry etching (Figure 3 (a)). Next, while distance S between the core trenches formed through the dry etching is measured accurately so as to regulate the indexes of refraction to obtain a desired characteristic, core film (17) made of a quartz glass material, such as SiO<sub>2</sub> doped with a refractivity controlling dopant, for example, TiO<sub>2</sub> or GeO<sub>2</sub>, or SiO<sub>x</sub>NyHz, is formed by means of the plasma CVD method, the sputtering method, or the ion beam method (Figure 3 (b)). Then, the extra portion of the core film is etched away through the dry etching step until WSi mask pattern (15) becomes exposed in order to form cores (18) (Figure 3 (c)).

[0016]

Then, said WSi mask pattern (15) is removed through the dry etching step (Figure 4 (a)). Finally, the quartz glass waveguide with the desired characteristic can be realized easily by covering [the entire surface] with cladding layer (19) made of the quartz glass material (Figure 4 (b)).

[0017]

Figure 5, Figure 6, and Figure 7 show another embodiment of the method for fabricating a quartz glass waveguide of the present invention.

[0018]

In Figure 5 (a), SiO<sub>2</sub> cladding layer (21) is formed on SiO<sub>2</sub> or Si substrate (20) by means of the plasma CVD method, the sputtering method, or the ion beam method. Then, WSi film (22) is formed subsequently by means of the sputtering method (Figure 5 (b)). Next, WSi mask pattern (23) for covering [the entire area] except the areas where cores are to be formed is formed through the photolithography step and the dry etching step (Figure 5 (c)).

[0019]

Then, core trenches (24) are formed by means of dry etching (Figure 6 (a)). Next, WSi mask pattern (23) is removed by dry etching (Figure 6 (b)). Next, while distance S between the core trenches is measured accurately so as to regulate the indexes of refraction to obtain a desired characteristic, core film (25) made of a quartz glass material, such as SiO<sub>2</sub> doped with a refractivity controlling dopant, for example, TiO<sub>2</sub> or GeO<sub>2</sub>, or SiO<sub>x</sub>NyHz, is formed by means of the plasma CVD method, the sputtering method, or the ion beam method (Figure 6 (c)). Then, based on a predetermined etching rate, dry etching is applied for the calculated duration of time required to etch the thickness of the extra portion of the core film so as to remove the extra portion of the core film in order to form cores (26) (Figure 7 (a)). Finally, the quartz glass waveguide with the desired characteristic can be realized easily by covering [the entire surface] with cladding layer (27) made of the quartz glass material (Figure 7 (b)).

[0020]

Next, results of experimental fabrication of a waveguide-type optical multiplexer-demultiplexer with the waveguide structure prototyped using the aforementioned method will be explained.

[0021]

Figure 1 (a) and (b) are outlines of the waveguide-type optical multiplexer-demultiplexer; wherein, Figure 1 (a) is an overall view, and Figure 1 (b) is a cross-sectional view along the a-a' axis of (a).

[0022]

First, as shown in Figure 1 (a), optical signal (27) with wavelengths  $\lambda_1$  and  $\lambda_2$  incident to the input side of the optical multiplexer-demultiplexer propagates inside of core (28-1), propagates into coupling region (29), and continues propagating while creating interference between core (28-1) and core (28-2); it is demultiplexed into optical signals with wavelength  $\lambda_1$

and  $\lambda_2$  and outputted from the output side of the optical multiplexer-demultiplexer as indicated by arrow (30-1) and arrow (30-2).

[0023]

In said configuration, distance S between respective cores (28-1) and (28-2) needs to be brought as closely to the designed value as possible in order to realize the demultiplexing at a low loss while attaining a high level of wavelength separation.

[0024]

Results of evaluations of the demultiplexing characteristics of optical multiplexer-demultiplexers prototyped when width W of cores (28-1) and (28-2) was 8  $\mu\text{m}$ , distance S between cores (28-1) and (28-2) was 5.5  $\mu\text{m}$ , and the difference in terms of relative index of refraction between core (28-1) (28-2) and cladding (28) was 0.25% are shown by the solid lines (optical multiplexer-demultiplexer created using the method of the present invention) and the dotted lines (multiplexer-demultiplexer created using the conventional method) in Figure 6 [sic; 8]. Here,  $\lambda_1 = 1.3 \mu\text{m}$  and  $\lambda_2 = 1.55 \mu\text{m}$  were used as designed values.

[0025]

While the one created using the method of the present invention showed hardly any deviation between the respective center wavelengths to be demultiplexed, the one created using the conventional method showed a significant deviation (approximately, 0.12  $\mu\text{m}$ ) between the center wavelengths. In addition, the results indicated that the one created using the method of the present invention had less propagation loss. The reason is that, because gap S between the trenches was measured after the trenches for the cores were formed through dry etching, and [the one] in accordance with the method of the present invention was created while regulating the index of refraction of the core film based on said value so as to attain the desired characteristic, a structure close to the designed values was able to be created.

[0026]

Effect of the invention

In sum, with the present invention, the distance between the trenches can be measured after the core trenches are formed through dry etching, and an optical multiplexer-demultiplexer can be created while regulating the index of refraction of the core film so as to attain the desired characteristic based on said value, so that the desired multiplexer-demultiplexer characteristic can be obtained. Therefore, a quartz glass waveguide with a desired characteristic can be created easily.



### Brief description of the figures

Figure 1 are outlined diagrams of a quartz glass waveguide obtained using the method of the present invention.

Figure 2 are diagrams for illustrating the method for fabricating a quartz glass waveguide of the present invention.

Figure 3 are diagrams for illustrating the method for fabricating a quartz glass waveguide of the present invention as the continuation of Figure 2.

Figure 4 are diagrams for illustrating the method for fabricating a quartz glass waveguide of the present invention as the continuation of Figure 3.

Figure 5 are diagrams for illustrating another method for fabricating a quartz glass waveguide of the present invention.

Figure 6 are diagrams for illustrating said other method for fabricating a quartz glass waveguide of the present invention as the continuation of Figure 5.

Figure 7 are diagrams for illustrating said other method for fabricating a quartz glass waveguide of the present invention as the continuation of Figure 6.

Figure 8 is a diagram showing the demultiplexing characteristics of optical multiplexer-demultiplexers prototyped using the method of the present invention and the conventional method.

Figure 9 are diagrams for illustrating the conventional method for fabricating a quartz glass waveguide.

Figure 10 are diagrams for illustrating the conventional method for fabricating a quartz glass waveguide as the continuation of Figure 9.

### Explanation of symbols

12, 20	Substrate
13, 21	Cladding layer
14, 22	WSi film
15, 23	WSi mask pattern
16, 24	Trench for forming core
17, 25	Core film
18, 26	Core formed by means of dry etching
19, 27	Cladding layer

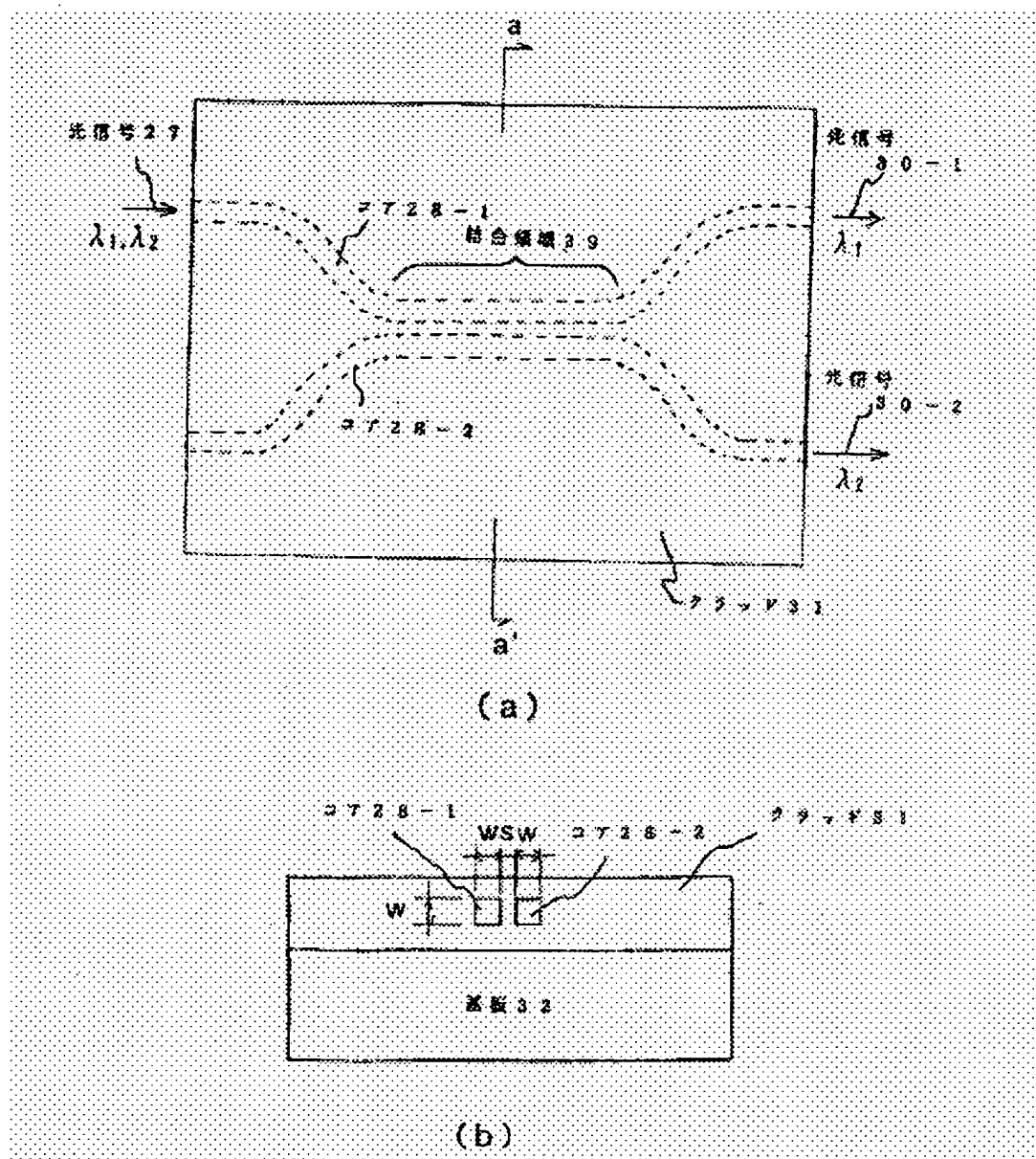


Figure 1

Keys: 27, 30-1, 30-2	Optical signal
28-1, 28-2	Core
29	Coupling region
31	Cladding
28-1, 28-2	Core
31	Cladding
32	Substrate

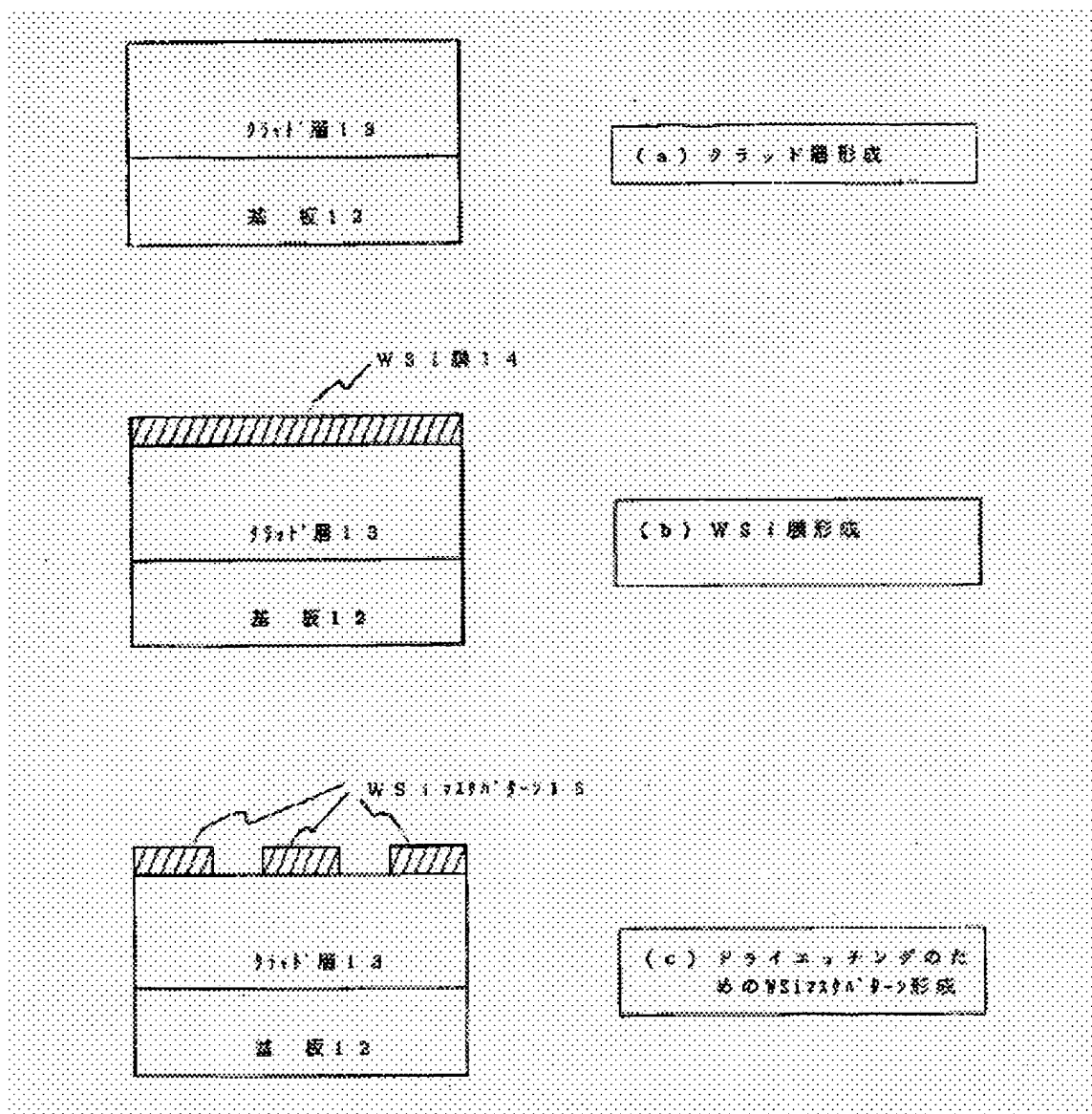


Figure 2

- Keys:
- (a) Formation of cladding layer
  - (b) Formation of WSi film
  - (c) Formation of WSi mask pattern for dry etching
  - 12 Substrate
  - 13 Cladding layer
  - 14 WSi film
  - 15 WSi mask pattern

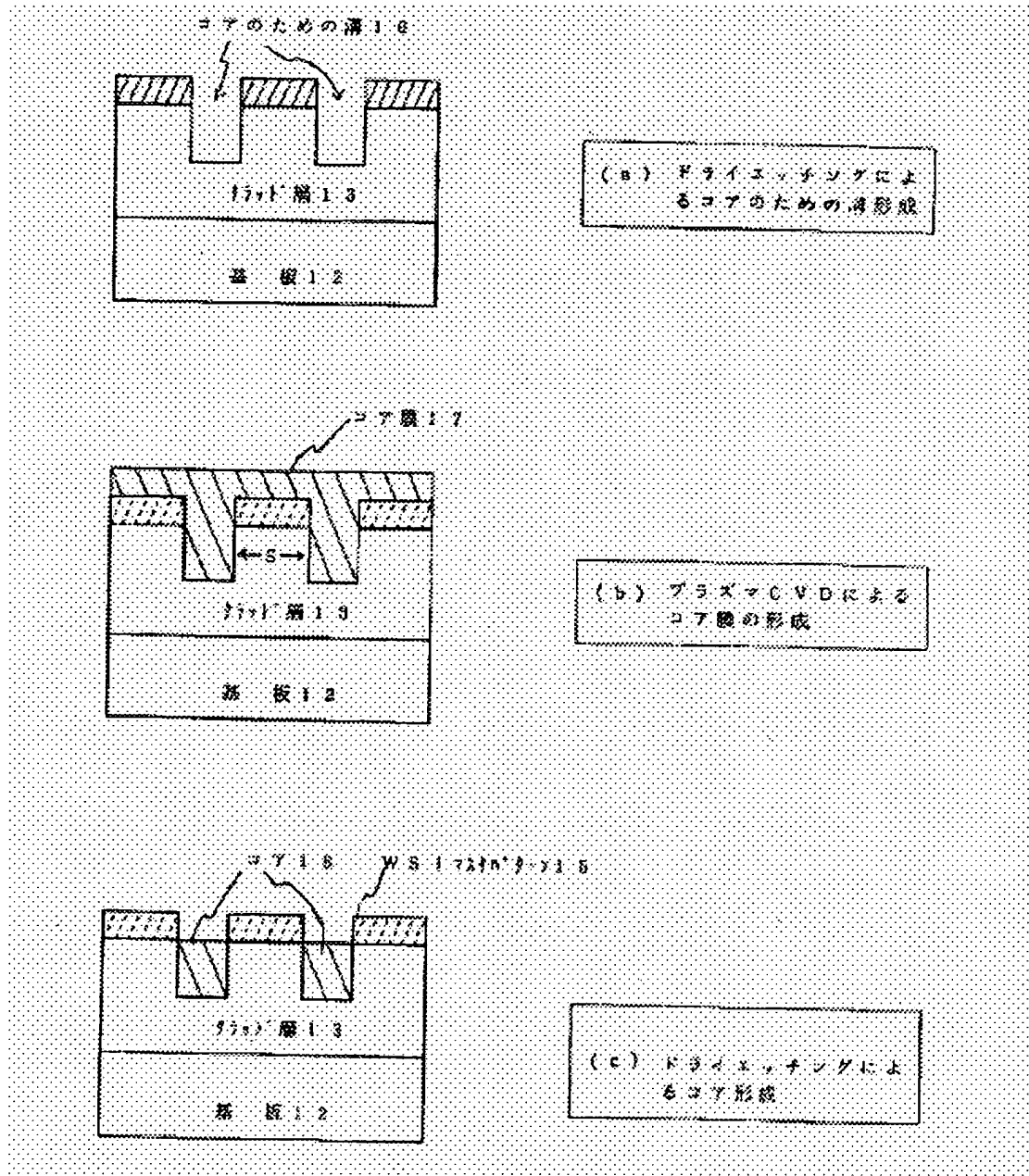


Figure 3

- Key:
- (a) Formation of trenches for cores by means of dry etching
  - (b) Formation of core film by means of plasma CVD
  - (c) Formation of cores by means of dry etching
  - 12 Substrate
  - 13 Cladding layer
  - 15 WSi mask pattern
  - 16 Trenches for cores
  - 17 Core film
  - 18 Core

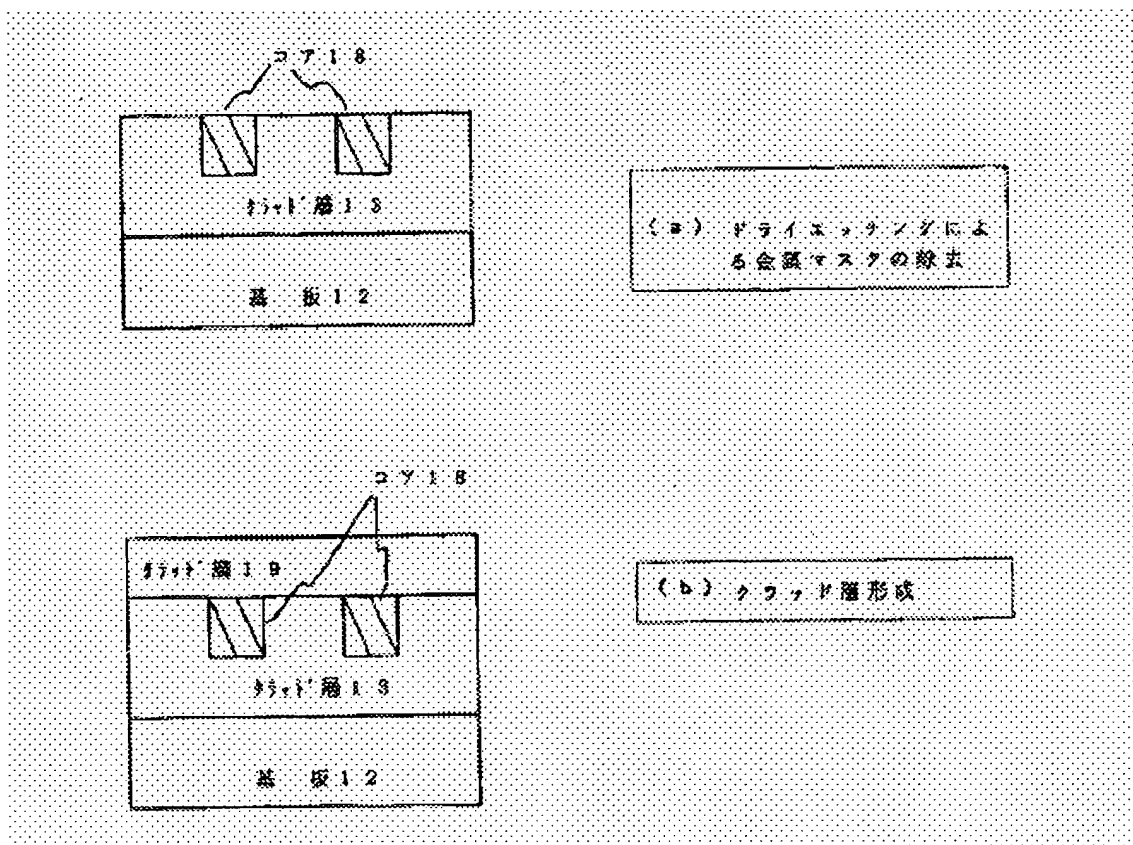


Figure 4

- Key:
- (a) Removal of metal mask by means of dry etching
  - (b) Formation of cladding layer
  - 12 Substrate
  - 13,19 Cladding layer
  - 18 Core

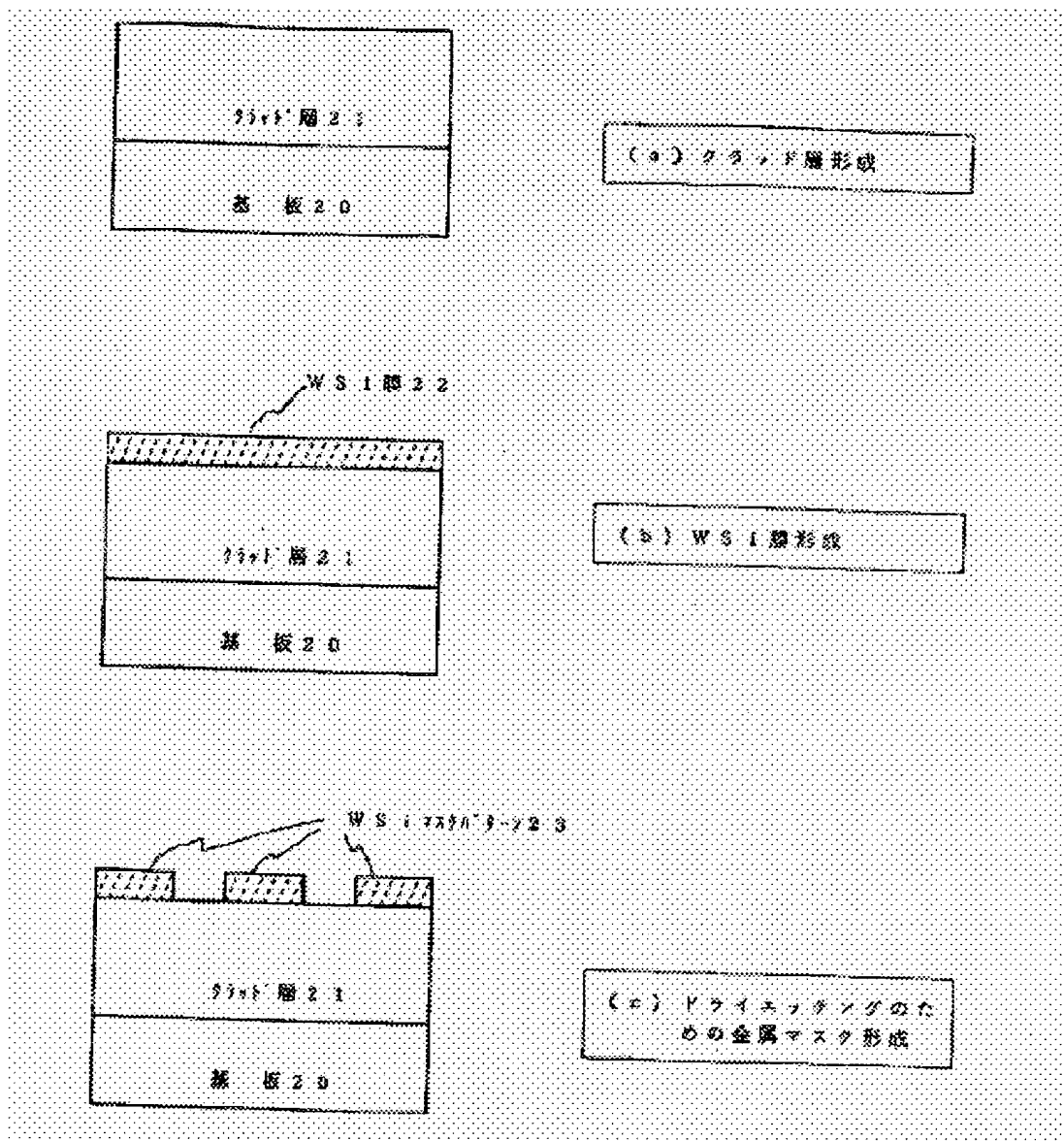


Figure 5

- Key:
- (a) Formation of cladding layer
  - (b) Formation of WSi film
  - (c) Formation of metal mask for dry etching
  - 20 Substrate
  - 21 Cladding layer
  - 22 WSi film
  - 23 WSi mask pattern

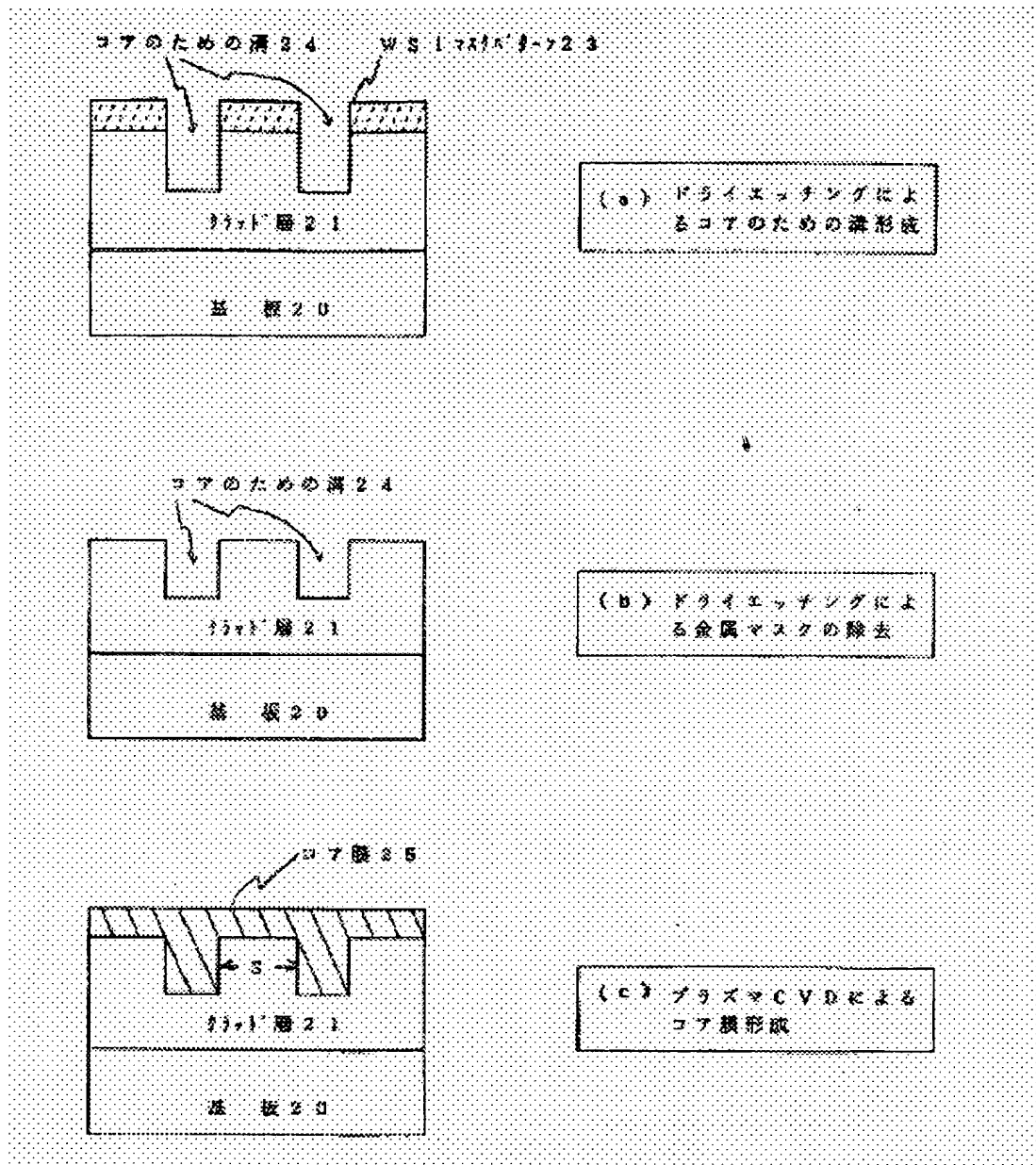


Figure 6

- Key:
- (a) Formation of trenches for cores by means of dry etching
  - (b) Removal of metal mask by means of dry etching
  - (c) Formation of core film by means of plasma CVD
  - 20 Substrate
  - 21 Cladding layer
  - 23 WSi mask pattern
  - 24 Trench for core
  - 25 Core film

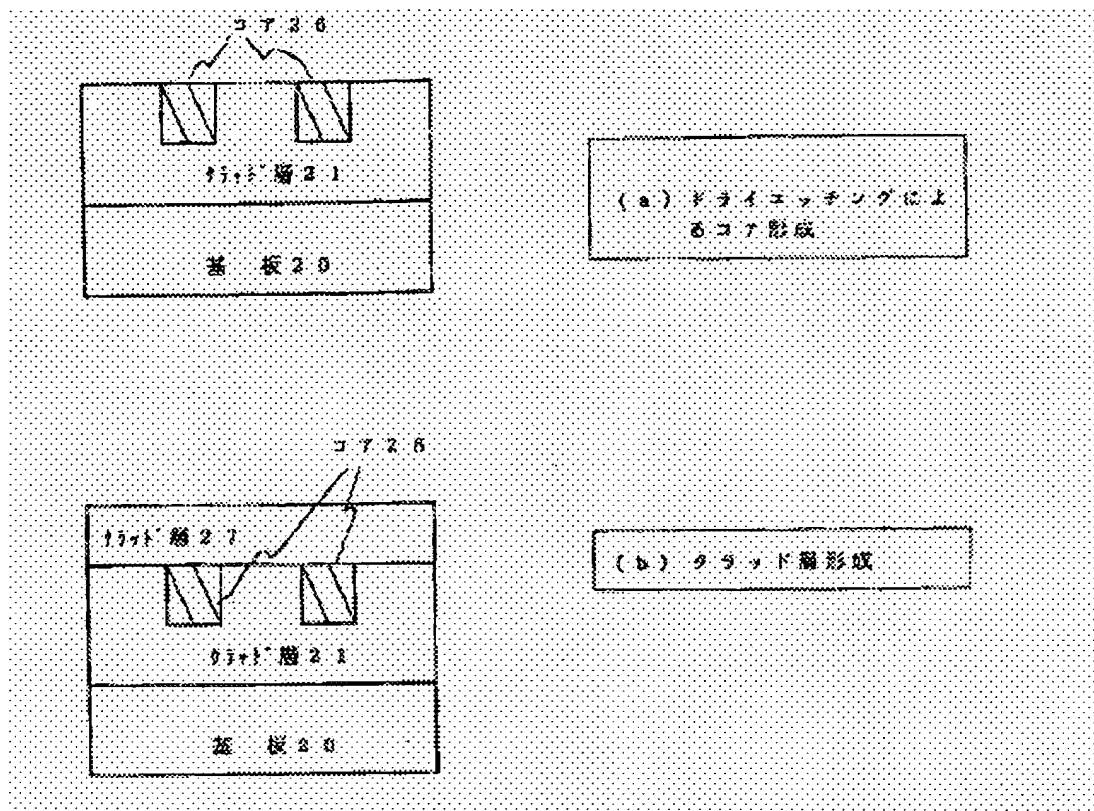


Figure 7

- Key:
- (a) Formation of core by means of dry etching
  - (b) Formation of cladding layer
  - 20 Substrate
  - 21, 27 Cladding layer
  - 26 Core



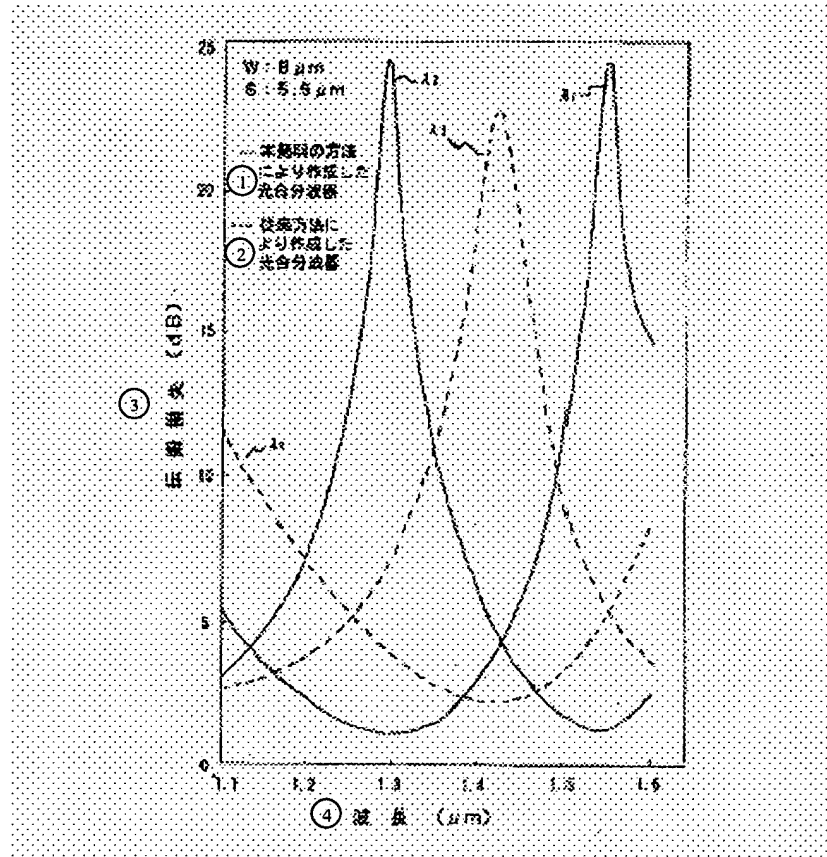


Figure 8

- Key:
- 1 Optical multiplexer-demultiplexer created using the method of the present invention
  - 2 Optical multiplexer-demultiplexer created using the conventional method
  - 3 Propagation loss
  - 4 Wavelength

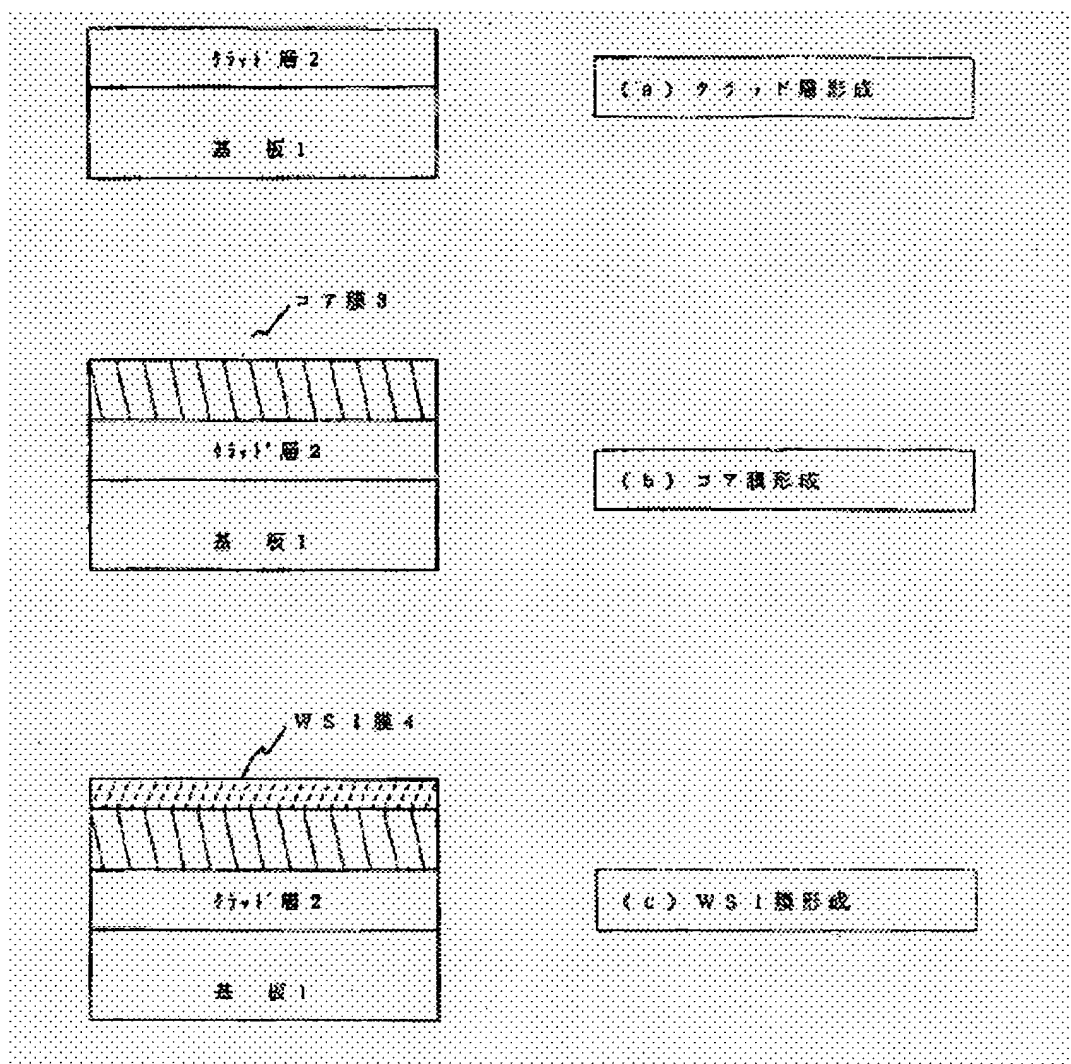


Figure 9

- Key:
- (a) Formation of cladding layer
  - (b) Formation of core film
  - (c) Formation of WSi film
  - 1 Substrate
  - 2 Cladding layer
  - 3 Core film
  - 4 WSi film

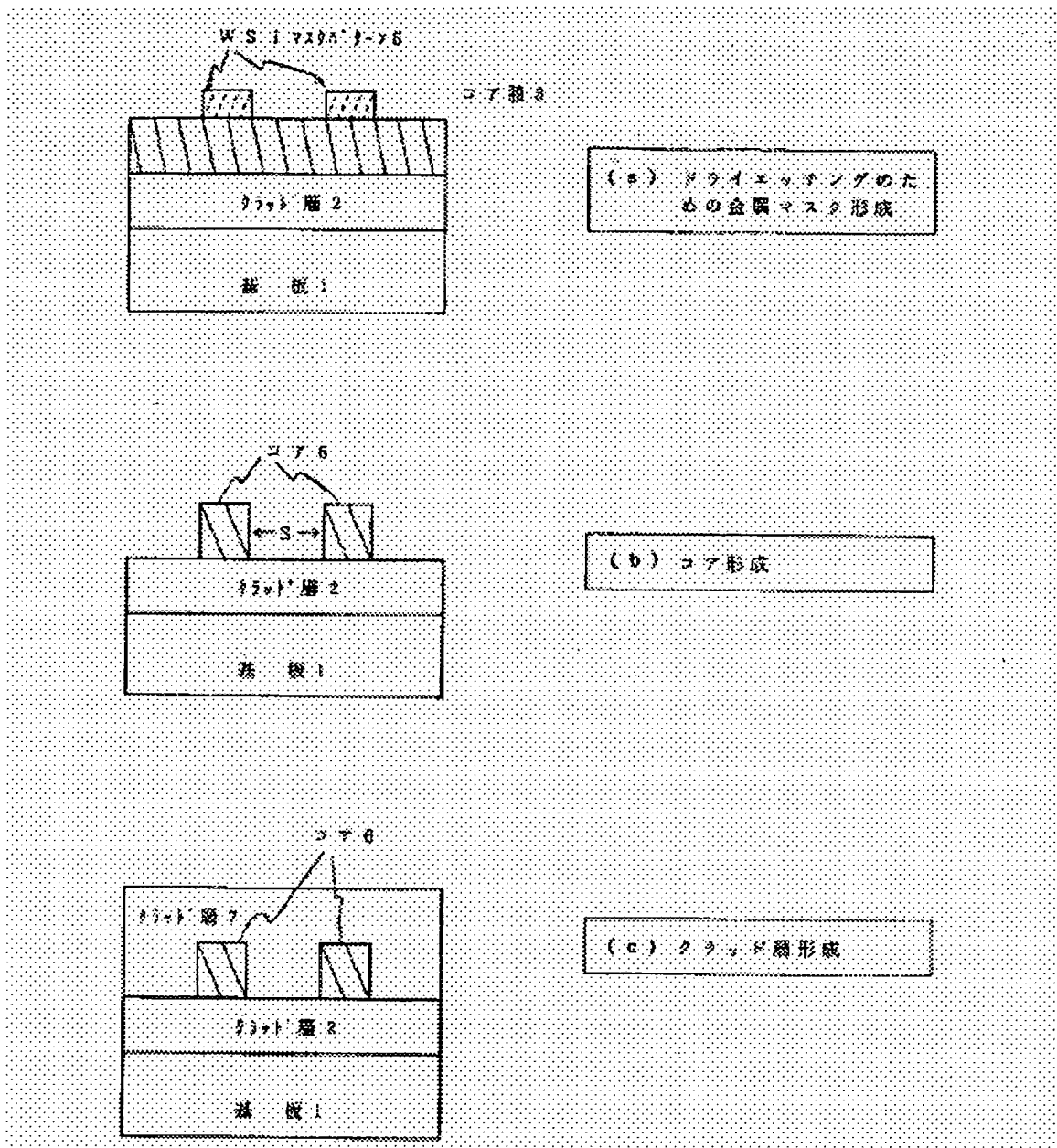


Figure 10

- Key:
- (a) Formation of metal mask for dry etching
  - (b) Formation of core
  - (c) Formation of cladding layer
  - 1 Substrate
  - 2, 7 Cladding layer
  - 3 Core film
  - 5 WSi mask pattern
  - 6 Core